**Dundee Discussion Papers in Economics 188**

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*Publication date:*
2006

# Dundee Discussion Papers in Economics

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Working Paper
No. 188
June 2006
ISSN:1473-236X

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## Abstract

*This paper provides a characterisation of the redistributive effects of agricultural policy, which yields consistent measures of horizontal inequities in the provision of support arising from both unequal treatment of pre-transfer income equals and systematic reranking of pre-transfer income unequals. An illustrative study shows that the distribution of support would have reduced farm income inequality in Scotland but for the adverse redistributive consequences of horizontal inequities, although neither systematic discrimination between farm types nor systematic reranking proves to be the major source of such inequities. The imperfect targeting of support revealed by the empirical findings has implications for policy design.*

**Keywords:** *Income redistribution; Agricultural Policy; Scotland.*

**JEL classifications:** *D63, I38, Q18.*

## 1. Introduction

The improvement of the income position of the agricultural community is a prominent if poorly defined objective of agricultural policy in many countries. In particular, one of the main objectives of the Common Agricultural Policy (CAP) is 'to ensure a fair standard of living for the agricultural community, in particular by increasing the individual earnings of persons engaged in agriculture' (European Union, 2002: Article 33). However the impact of farm support programmes on the distribution of income among farmers has received little explicit consideration in the mainstream literature on the redistributive effects of agricultural policy which has focused instead on the optimal choice of instruments to transfer surplus from consumers and taxpayers to producers, that is on efficiency rather than equity issues. The conventional wisdom on the subject is summarised in Organisation of Economic Cooperation and Development (OECD, 2003) which argues that farm support measures do not change the income distribution in any significant way because they are still primarily based on production or production factors. Moreover the generic nature of many measures implies that the bulk of support goes to farms that do not need it. OECD agricultural ministers (OECD, 1998) have identified equity and targeting as operational criteria for policy evaluation.

In general terms, the redistributive effect of agricultural policy may be defined as the difference between the inequality of farm incomes without and with the transfers accruing from the provision of support. In a series of papers, Allanson (2005a, 2005b, 2006) finds that the CAP would have reduced inequality in Scottish farm incomes, both in absolute and relative terms, but for the adverse distributional consequences of horizontal inequities induced by farm support measures. But whereas Allanson (2005b) identifies horizontal inequities with the violation of the classical principle of the equal treatment of pre-transfer income equals, Allanson (2005a, 2006) associates them with the procedural unfairness manifest in the reranking of farms between the pre-transfer and post-transfer income distributions. The first approach leads Allanson (2005b) to conclude that the CAP is ineffective as a redistributive tool because the poor targeting of support results in wide differences in the level of benefits received by farmers with the same level of pre-transfer farm income, whereas the second prompts Allanson (2005a, 2006) to speculate that the main problem is that farmers have to engage in otherwise unprofitable activities in order to benefit from support. The main methodological contribution of this paper is to provide a framework in which the two conceptually distinct notions of horizontal inequity (HI) can be jointly measured in a consistent manner so as to better inform the design of agricultural policy.

The seminal paper on the joint measurement of classical HI and reranking effects is Aronson *et al.* (1994) which proposes a decomposition of the change in inequality due to the unequal treatment of pre-transfer equals. Duclos *et al.* (2003) have since established a clear normative basis for this type of decomposition by distinguishing between welfare losses due to aversion to post-transfer income uncertainty and relative deprivation respectively. But this distinction is of little practical import from a policy design perspective as the common response to both concerns will be to reduce the degree of dispersion of post-transfer incomes about expected levels conditional upon pre-transfer income. Furthermore, Aronson *et al.* (1994) explicitly rule out consideration of systematic reranking due to the presence of non-monotonicities in the relationship between pre-transfer and expected post-transfer incomes, on the grounds that such reranking will constitute an intentional vertical policy effect. But the presence of income traps in transfer schedules may more often reflect a defect of policy design, in that economic agents will face positive incentives to reduce their pre-transfer incomes over some range, thereby increasing welfare dependence and policy costs.

Accordingly, this paper offers an alternative decomposition between a classical HI effect due to the unequal treatment of pre-transfer equals and a systematic reranking effect, where the former is further decomposed, in the spirit of Kakwani and Lambert (1999), to provide measures of the effect of systematic discrimination between different groups of farmers. The key to the methodology is the specification and estimation of a set of 'reference' functions that determine the post-transfer incomes that farmers with a given level of pre-transfer income would receive in the absence of particular sources of HI. The overall redistributive effect of policy, measured as the difference between the absolute Gini indices of pre-transfer and post-transfer incomes, can thereby be decomposed into a vertical equity component, which is determined by the progressivity and scale of support, and the various sources of HI. The resultant measures serve to characterise the redistributive properties of the observed provision of support given the existing distribution of pre-transfer incomes. That is to say, the measures do not allow for the impact of policy-induced changes in farm production choices, the state of agricultural input and output markets or agricultural structures on either the incidence of transfers or pre-transfer incomes. Nevertheless, the approach usefully offers a novel perspective on the redistributive performance of agricultural policy.

The paper is organised as follows. The next section introduces the measures that are used to characterise and quantify the redistributive effects of agricultural policy. The third section presents an empirical illustration based on weighted micro-level data from the Scottish Farm Accounts Survey for the financial years 2000/01 through 2004/05. The final section offers a summary and some brief concluding remarks on the implications of the empirical findings for the design of agricultural policy.

## 2. Measurement of the redistributive effects of agricultural policy

Adopting the standard change-in-inequality approach, the redistributive effect of agricultural policy is defined as the difference between the inequality of pre-transfer and post-transfer farm incomes. However, the choice of inequality measure for this purpose is constrained by the incidence of negative farm incomes or losses, because many standard aggregative measure of inequality are either undefined for negative incomes (Amiel *et al.*, 1996) or, if defined, do not give rise to well-behaved measures of redistribution if pre-transfer incomes are negative on average.[1] In particular, conventional measures of relative inequality are not suitable for the purpose because the sign of this type of measure is determined by the sign of average income. Thus if average pre-transfer income is negative whereas average post-transfer income is positive then the resultant measure of redistribution will be negative irrespective of the effect of support on inequality (Allanson, 2006).

One solution to this problem is to base the analysis on some measure of absolute inequality. These measures have the appealing property for the study of farm support programmes that they are invariant to equal absolute changes to all incomes. Thus a flat-rate payment to all farmers will be deemed to be distributionally neutral in that it will have no effect on absolute inequality. In contrast, relative inequality measures are scale invariant such that a policy which changes all incomes in the same proportion will be judged to have no redistributive effect. But the presumed proportionality of transfers is precisely the basis of the widespread criticism of existing farm support programmes as poorly targeted and inequitable (see, inter alia, European Commission (EC), 2002; OECD 2003; Oxfam 2004).

Accordingly, $R=A_X-A_Y$ is defined as an index of the overall redistributive effect of farm income support, where $A_X$ and $A_Y$ are the absolute Gini indices of pre-transfer and post-transfer incomes respectively. The absolute Gini index $A$ is defined as half the average absolute difference between all distinct pairs of incomes in the population.[2] But it is also equal to the product of the (ordinary) Gini coefficient $G$ and average income $\bar{y}$, which suggests a normative interpretation of $R$ with reference to the welfare measure $W = \bar{y}(1-G) = \bar{y} - A$ of Sen (1973). Let $W_Y$ be welfare in the post-transfer income distribution and $W_E$ be welfare under a hypothetical policy of flat-rate payments equal in total value to the actual support programme, then $R = W_Y - W_E$, since $A_E = A_X$, which can be interpreted as the monetary value of the redistributive effects of the policy expressed on an individual farm basis. That is to say, $R$ represents how much more or less would have to be given to each farmer under the distributionally neutral policy of flat-rate payments to yield a welfare level equal to that under the actual support programme.

*2.1 Decomposition of the overall redistributive effect*

The key to the decomposition of the index of overall redistributive effect $R$ into horizontal and vertical components is the specification and estimation of a set of 'reference' functions, where each function provides a unique mapping from pre-transfer to post-transfer incomes in the absence of a particular source of HI (see Jenkins and Lambert, 1999). The full decomposition yields $R = H_W + H_B + H_R + V$, where $H_W$ and $H_B$ measure the redistributive effects of within and between farm type sources of classical HI, $H_R$ is a systematic reranking effect, and the 'pure' vertical equity component $V$ is determined by the scale and progressivity of transfers

The starting point for the decomposition procedure is the observation that the provision of agricultural support in most countries comprises a number of more or less distinct commodity regimes, with the incidence of transfers within each regime typically determined by some particular combination of current and/or historical levels of production and/or factor usage. For example, the CAP consists of various common market organisations that differ both in terms of the choice of support instruments and the overall level of support that is provided to farmers (see Agra Informa (2006) for a comprehensive guide). To explore the implications of the commodity organisation of agricultural policy requires the specification of not one but a whole set of reference functions, where each function would ideally apply to a discrete group of farmers producing a particular commodity (e.g. cereal growers, milk producers etc.). However many farms produce more than one commodity and farm accounts data typically do not permit identification of the contribution of each to overall farming income due to the incomplete allocation of costs. Accordingly, separate functions are defined not for each producer group but for distinct sub-populations of farms producing more or less similar combinations of commodities (e.g. cereal farms, dairy farms etc.).

Consider a population of $N$ farms made up of an exhaustive set of $K$ mutually exclusive farm types ($k$ = 1,... $K$). Let $\boldsymbol{y}=(\boldsymbol{y_1},\ldots \boldsymbol{y_k},\ldots \boldsymbol{y_K})$, $\boldsymbol{t}=(\mathbf{t_1},\ldots \boldsymbol{t_k},\ldots \boldsymbol{t_K})$ and $\boldsymbol{x}=(\boldsymbol{x_1},\ldots \boldsymbol{x_k},\ldots \boldsymbol{x_K})$ be the vectors of observations on post-transfer income, transfers and pre-transfer incomes respectively, where $\boldsymbol{y_k}$, $\boldsymbol{t_k}$, and $\boldsymbol{x_k}$ are constituent sub-vectors of observations on farms of type $k$. Following Aronson *et al.* (1994), the relationship between post-transfer and pre-transfer incomes is written as:

$$\boldsymbol{y_k} \;=\; g_k(\boldsymbol{x_k}) + \boldsymbol{\varepsilon_k} \;=\; \mathrm{E}[\boldsymbol{y_k}|\,\boldsymbol{x_k}] + \boldsymbol{\varepsilon_k} \;=\; \boldsymbol{x_k} + \mathrm{E}[\boldsymbol{t_k}|\,\boldsymbol{x_k}] + \boldsymbol{\varepsilon_k}; \qquad k = 1,\ldots.K \tag{1}$$

where $g_k(\boldsymbol{x_k})$ is identified as the reference function for type $k$ farms and defined as the farm type specific expected value of post-transfer income conditional upon pre-transfer income; and $\boldsymbol{\varepsilon_k}$ is interpreted as a vector of 'disturbance' terms having zero mean at each pre-transfer income level. The shape of the farm type reference functions will be determined by the way in which expected transfers vary with pre-transfer income, where the magnitude of both will be roughly proportionate to the scale of production as a general rule. However the precise form of this relationship will not typically be specifiable given the complexity of both commodity regimes and agricultural production processes. Accordingly, the set of $g_k(\boldsymbol{x_k})$ functions are simply assumed to be continuous, smooth functions, yielding a non-parametric model with only very weak constraints on its structure. The disturbance term $\boldsymbol{\varepsilon_k}$ allows for the possibility that farms of type $k$ with identical pre-transfer incomes may receive different levels of support due to differences in natural resource endowments, managerial ability and historical development. For example, commodity regimes in which the receipt of support is linked to current input and output levels are likely to give rise to some dispersion of transfers since a range of input and output combinations may be associated with any given level of pre-transfer income due to differences between farms in the utilisation and productivity of resources. While in decoupled payment schemes based on historical entitlements, any link between the incidence of support and pre-transfer incomes through current production choices is expressly broken.

*Identification of $H_W$ and $H_B$*

The characterisation of post-transfer incomes given by (1) allows for two possible sources of classical HI. First farms of type $k$ with identical pre-transfer incomes may have different post-transfer incomes due to the disturbance term $\boldsymbol{\varepsilon_k}$, with the degree of dispersion of post-transfer incomes $\boldsymbol{y_k}$ about the conditional mean $\mathrm{E}[\boldsymbol{y_k}|\,\boldsymbol{x_k}]$ reflecting the extent of within type HI. Only if $\boldsymbol{\varepsilon_k}=\mathbf{0}$ will there be a one-to-one mapping from pre-transfer to post-transfer incomes for type $k$ farms and hence no within type HI. Accordingly, $h_W(\boldsymbol{x})=(g_1(\boldsymbol{x_1}),\ldots g_k(\boldsymbol{x_k}),\ldots g_K(\boldsymbol{x_K}))$ is interpreted as the vector of post-transfer incomes that the population of farms would receive in the absence of within type HI. Let $\mathrm{A}_W$ be the absolute Gini index of $h_W(\boldsymbol{x})$ then $H_W=\mathrm{A}_W-\mathrm{A}_Y$, that is within type HI is measured as the difference in inequality between $h_W(\boldsymbol{x})$ and $\boldsymbol{y}$, which will be non-positive.[3]

The other potential source of classical HI is due to systematic discrimination between farm types. As the $g_k(\boldsymbol{x_k})$ functions are type specific, farms with identical pre-transfer incomes may have different expected post-transfer incomes depending on type, with the scale of divergences between the functions reflecting the extent of between type HI. Only if

$g_k(\boldsymbol{x_k}) = g(\boldsymbol{x_k})\ \forall k$, and hence $h_W(\boldsymbol{x}) = g(\boldsymbol{x})$, will there be a one-to-one mapping from pre-transfer incomes to expected post-transfer incomes for all farms and hence no between type HI. The measurement of between type HI requires the identification of a non-discriminatory reference function $h_B(\boldsymbol{x})$ determining the post-transfer incomes that the whole population of farms could expect to receive in the absence of discrimination between farm types. In the absence of any established theory to guide the specification of this function and in keeping with the treatment of within type HI, $h_B(\boldsymbol{x})$ is specified on the assumption that discrimination between farm types changes the distribution but not the overall value of transfers at any given pre-transfer income. It follows that $h_B(\boldsymbol{x})=\mathrm{E}[\boldsymbol{y}|\,\boldsymbol{x}]$, that is the mean value of post-transfer income conditional upon pre-transfer income but not farm type, will be given as a weighted sum of the post-transfer income functions for the individual types:

$$h_B(\boldsymbol{x}) = \sum_{k=1}^{K} w_k(\boldsymbol{x})\, g_k(\boldsymbol{x}); \qquad \sum_{k=1}^{K} w_k(\boldsymbol{x}) = \mathbf{1} \tag{2}$$

where the weights $w_k(\boldsymbol{x})$ are locally determined by the relative frequencies of the farm types at any given pre-transfer income, rather than being globally determined by the proportions of each type in the population, and **1** is the unit vector. Let $\mathrm{A}_B$ be the absolute Gini index of $h_B(\boldsymbol{x})$ then $H_B=\mathrm{A}_B-\mathrm{A}_W$, that is between type HI is measured as the difference in inequality between $h_B(\boldsymbol{x})$ and $h_W(\boldsymbol{x})$, which will again be non-positive.[4]

By definition, total classical HI will equal the sum of within and between type classical HI, that is $H_W+H_B=A_B-A_Y$. Only if $\boldsymbol{y}=h_B(\boldsymbol{x})$ will there be a one-to-one mapping from pre-transfer to post-transfer incomes for all farms and hence no classical HI. More generally, the degree of dispersion of post-transfer incomes $\boldsymbol{y}$ about the non-discriminatory function $h_B(\boldsymbol{x})$ will reflect the total extent of classical HI in the provision of agricultural support.

*Identification of $H_R$ and V*

The identification of the contribution of classical HI to the overall redistributive effect $R$, leaves a residual equal to the difference in inequality between pre-transfer and non-discriminatory post-transfer incomes, $A_X - A_B$. The final step in the decomposition procedure rests implicitly on the construction of a further reference function $h_R(\boldsymbol{x})$, which assigns the $r$'th $(r=1,...N)$ largest non-discriminatory post-transfer income to the observation ranked $r$ in the distribution of pre-transfer income $\boldsymbol{x}$, to decompose this residual along the lines of Kakwani (1984) into separate horizontal and vertical equity components:

$$A_X - A_B = \bar{y}_B[C_B - G_B] + [\bar{x}G_X - \bar{y}_B C_B] = H_R + V \tag{3}$$

where $G_X$ and $G_B$ are the (ordinary) Gini coefficients of pre-transfer and non-discriminatory post-transfer income, $\bar{x}$ and $\bar{y}_B = \bar{y}$ are the corresponding mean incomes, and $C_B$ is the concentration index obtained when non-discriminatory post-transfer incomes are ranked by pre-transfer income.[5]

The 'horizontal' component $H_R$ in (3) measures the redistributive effect of systematic changes in the ranking of farms between the pre-transfer and non-discriminatory post-transfer income distributions, where $[C_B - G_B]$ may be identified as the reranking index of Atkinson (1980) and Plotnick (1981).[6] $H_R$ is non-positive by definition (Atkinson, 1980), implying that any systematic reranking that does occur has a negative impact on the overall redistributive effect $R$. Only if $h_B(\boldsymbol{x})$ is increasing in $\boldsymbol{x}$ over the whole range of pre-transfer incomes will there be no systematic reranking of farms. Note that monotonicity of the farm type functions in (1) is neither a necessary nor sufficient condition because the slope of $h_B(\boldsymbol{x})$ is also sensitive to farm type composition effects given the local determination of the weights in (2).

Finally the vertical equity component $V = [\bar{x}G_X - \bar{y}_B C_B] = - C_{T_B}\bar{t}_B$ provides a measure of the effects of differences in non-discriminatory policy transfers between farms with different pre-transfer incomes, which may be interpreted as an index of gross redistributive effect. This in turn depends on the distribution and scale of policy transfers where $C_{T_B}$ is the concentration coefficient of non-discriminatory transfers ranked by pre-transfer income[7] and $\bar{t}_B$ is the mean level of non-discriminatory transfers. Let $D = - C_{T_B}$ be a disparity index that is positive (negative) if support is progressive (regressive) in absolute terms such that mean non-discriminatory transfers are a decreasing (increasing) function of pre-transfer income, and that equals zero if the transfer schedule is uniform. For any given $D$, the gross redistributive effect of the policy will be proportional to the average level of non-discriminatory transfers $\bar{t}_B$. In general, $V$ will be greater (i.e. more positive) than $R$ due to the various sources of HI that will typically undermine the redistributive effectiveness of policy.

*2.2 Reference function estimation*

The set of farm type reference functions (1) can be estimated from a sample consisting of $n_k$ observations on pre-transfer and post-transfer incomes for each farm type. The estimation of these functions implicitly resolves the identification problem inherent in classical approaches to the measurement of HI in the absence of observations on exact pre-transfer income equals (Duclos and Lambert, 2000). The choice of a suitable non-parametric technique for the purpose gets round the need to impose any parametric assumptions on their form.

Here the variable span smoother of Sasieni (1998) is used to fit a local linear regression to the observations on $\boldsymbol{y_k}$ and $\boldsymbol{x_k}$ in the neighbourhood of each data point in the sample. The number of observations used to fit the model at each data point is determined by the variable span of the smoother, which is calculated by initially choosing the span at each data point that minimises the cross validated mean squared prediction error and then smoothing the resultant series of values.[8] The use of a local linear regression estimator may be expected to provide a reasonable approximation to $g_k(\boldsymbol{x_k})$ so long as the curvature of the unknown function is not excessive. In contrast, the local mean estimators that have commonly been employed in the literature on the measurement of classical HI (see, for example, Kakwani and Lambert, 1999; Van der Ven *et al.*, 2001; Rodríguez *et al.*, 2005) would likely be subject to bias as the slopes of the reference functions are expected to be non-zero and the spacing of sample observations on pre-transfer incomes is not uniform (Hastie and Loader, 1993). Furthermore the choice of estimator allows the use of inferential procedures that are analogous to those familiar from the least-squares fitting of parametric functions (Cleveland and Devlin, 1988).

The non-discriminatory function $h_B(\boldsymbol{x})$ can in principle be calculated using (2) given the non-parametric estimates of the farm type functions $g_k(\boldsymbol{x_k})$ and kernel density estimates of the weight functions $w_k(\boldsymbol{x_k})$ (see Kakwani and Lambert, 1999). However, reliable estimates of the weights functions will not be obtainable if, as will usually be the case, the number of observations on each farm type is limited to such an extent that it results in sparseness of the data over the observed range of pre-transfer incomes. An alternative approach is therefore adopted in which $h_B(\boldsymbol{x})$ is directly estimated using the same local regression technique that is used to estimate the set of functions in (1), but applied to the pooled sample of $n=\sum n_k$ observations. This procedure ensures that the predicted level of non-discriminatory post-transfer income at any given level of pre-transfer income will automatically reflect the farm type composition of the sample in the neighbourhood of that point. Finally the reference function $h_R(\boldsymbol{x})$ can be obtained simply by reassignment of the estimates of non-discriminatory post-transfer income.

## 3. Illustrative application: Scotland, 2000/01-2004/05

The methodology is illustrated by an empirical study of the redistributive effects of agricultural support in Scotland. The study is based on weighted micro-level data from the Scottish Farm Accounts Survey (FAS) for the financial years 2000/01 through 2004/2005, the most recent year for which results are available and the last before the replacement of most production-related direct support payments by the decoupled single farm payment.

*3.1 Data*

Calculation of measures of redistributive effect requires access to individual farm data on pre-transfer and post-transfer incomes. The FAS is an annual survey of approximately 450 full-time farms carried out on behalf of the Scottish Executive Environment and Rural Affairs Department (SEERAD) and provides the main source of microeconomic data on farm businesses in Scotland.[9] The survey is conducted on an accounting year basis with a typical year-end in early March so, for example, the 2000/01 FAS centres on the 2000 production and subsidy year. The farms in the survey are chosen to be representative of their size and type, where the economic size of the business is measured in terms of standard gross margin prior to 2003/04 and standard labour requirement thereafter, and the farm type classification is based on the relative importance of the various crop and livestock enterprises in terms of standard gross margin.[10] Data is collected on a wide range of physical and financial variables, including crop areas, livestock numbers, quotas, production, sales, revenues, subsidies and costs, which allows for the identification of both farm income and policy transfers. The data is weighted by size and type according to the number of farms enumerated in the annual June Agricultural Census, to yield summary statistics for the population of full-time farms. Given an average population of 14416 farms in the sampling frame, the average sampling fraction for each size and type is 2.9 per cent over the period.

Post-transfer income is measured by Cash Income, which is a measure of farm income that represents the cash return to the group with an entrepreneurial interest in the farm[11] for their manual and managerial labour and on all their investment in the business. As the difference between total receipts and total expenditure, the measure is interpreted as corresponding closely to the income position as perceived by the farmer (Department of the Environment Food and Rural Affairs (DEFRA), 2002). Nevertheless, the FAS does not provide sufficient information on either non-farm sources of income or farm household composition to support an analysis of the distributional effects of support on the overall welfare of the agricultural community. The analysis is conducted at the farm level rather than per unit of unpaid labour because of doubts concerning the relevance and reliability of data on the unpaid labour input in the UK context (see Hill 1991).

Pre-transfer income is simply defined as Cash Income less the net value of transfers due to the provision of support, where the latter is assumed equal to that part of gross support which accrues to farm occupiers as owners of factors of agricultural production. Three types of support are identified in the analysis. First, with respect to market price support measures, estimates are taken from the OECD PSE database (OECD 2005) of the gap between domestic market and border prices for the main agricultural commodities, measured at the farmgate level. These estimates are used to calculate the impact of price support in terms of inflating both the market value of observed output quantities and the cost of purchased feed and seed inputs. Second, direct support payments cover those payments made under CAP direct support schemes (also known as 'Pillar I' schemes).[12] In calculating the net value of these payments, account is taken of the implicit loss in revenues resulting from obligatory set-aside requirements under the Arable Area Payment scheme. Third, the value of other grants and subsidies includes all other payments to farmers except for those in respect of permanent improvements.

The net value of this support to farmers will depend on the extent to which it results in increased returns to the farm-owned factors of production, including management, and hence in increased farm incomes. Following OECD (2003, Part II), the static effect on farm income of a unit increase in output revenues, whether due to market price support, output payments or a reduction in set-aside requirements, is identified as the combined cost share of the farm-owned factors of production, while that of a unit increase in direct payments, grants or subsidies to individual inputs (i.e. land and breeding livestock) is simply the farm-owned share of those inputs. This approach recognises that farmers may not be the ultimate beneficiaries of agricultural support programmes, which may also serve to benefit landlords, hired workers, and off-farm input suppliers among others. Moreover, the effective incidence of support is allowed to vary depending on the way in which that support is provided.

Estimates of factor cost shares are obtained on the assumption that Scottish agriculture may be characterised by an aggregate Cobb-Douglas production technology exhibiting constant returns to scale.[13] Farm-specific fixed effects are included in the model to allow for the (fixed) management input (Mundlak, 1961), and the parameters of the Cobb-Douglas production function estimated by means of the within-groups estimator using an unbalanced panel consisting of the weighted FAS data for 2000/01 through 2004/05. The results reported in Table 1 yield cost shares estimates for total labour, land and buildings, livestock capital, and all other purchased inputs of 12.9%, 6.6%, 17.2%, and 38.4% respectively. With these attributable costs accounting for 75.2% of total revenue, the residual 24.8% is identified as the return to the farmer's management. Farm-owned shares of factors of production are derived for each farm in the FAS sample, with 81.3% of labour, 57.4% of land and buildings and 100% of livestock capital being supplied on average by farmers over the period. Hence the average benefit to farmers of an extra £1 of market price support or output-related payments, of area-related payments, of headage payments, subsidies or grants on breeding livestock, and of purchased input subsidies, would have been £0.564, £0.574, £1 and £0 respectively.

*3.2 Empirical findings*

The upper panel of Table 2 presents weighted summary statistics by year for all farm types. Average post-transfer income per farm was positive throughout the period, although a small proportion of farms in each year recorded losses in spite of the support available. The main source of support was provided in the form of direct payments but market price support was also significant with domestic producer prices for most livestock products remaining well above corresponding world price levels. Leakages to other owners of factors of production mean that farmers are estimated to have received only 66% of the gross value of support on average. Nevertheless, the value of these transfers to farmers was of the same order of magnitude as post-transfer incomes throughout the period, implying that average incomes would have been close to zero had it not been for the provision of support. Indeed more than half of farms in each year would have recorded losses, highlighting the chronic dependence of farming on state aid.

Table 1. Within-groups Estimates of the Cobb-Douglas Production Function

| Variable | Coefficient | Robust s.e | t-ratio | p-value |
|---|---|---|---|---|
| Labour | 0.129 | 0.057 | 2.270 | 0.024 |
| Land and buildings | 0.066 | 0.036 | 1.860 | 0.063 |
| Livestock | 0.172 | 0.041 | 4.160 | 0.000 |
| Other purchased inputs | 0.384 | 0.077 | 4.950 | 0.000 |
| Dummy 2001/02 | 0.086 | 0.019 | 4.500 | 0.000 |
| Dummy 2002/03 | 0.075 | 0.022 | 3.470 | 0.001 |
| Dummy 2003/04 | 0.134 | 0.019 | 6.940 | 0.000 |
| Dummy 2004/05 | 0.045 | 0.019 | 2.320 | 0.021 |
| Constant | 3.921 | 1.030 | 3.810 | 0.000 |
| Overall $R^2$ = 0.964 | Within-groups $R^2$ =0.133 | | Between-groups $R^2$ =0.997 | |
| Sample size = 1942 | | F(8,1387) = 16.19 | Number of groups = 546 | |

Notes: The dependent variable in the model is the value of farm output, excluding direct payments, other grants and subsidies. The explanatory variables are: (i) total labour use in annual work units (ii) cost of land and buildings, including the imputed cost of owner-occupied land (iii) value of livestock capital, defined as the average of the opening and closing valuations (iv) cost of all other purchased inputs, covering the FAS machinery, crop, livestock and miscellaneous cost categories (v) dummy variables for the years 2001/02 through 2004/05, with 2000/01 defined as the base year. The data on costs and values are deflated by the relevant Agricultural Price Index (base year=2000; online: http://statistics.defra.gov.uk/esg/datasets/apiyear.xls), except for those on land costs and livestock values for which dedicated price indices by farm type and by livestock type respectively are constructed from the FAS panel. All variables other than the year dummies are expressed in natural logarithms. Fixed effects are not reported.

Table 2. Weighted Summary Statistics by Year and Farm Type, 2000/01–2004/05

| *By year for all farm types* | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 |
|---|---|---|---|---|---|
| | | | *Average per farm* | | |
| Number of observations | 450 | 386 | 376 | 444 | 460 |
| Farm business size (ESU) | 63 | 63 | 64 | 53 | 54 |
| Post-transfer income (£) | 28641 | 29523 | 27610 | 36570 | 36327 |
| *Proportion of farms <0* | 6.3% | 8.4% | 9.7% | 4.0% | 5.9% |
| Gross support (£) | 41975 | 42631 | 46771 | 49711 | 57007 |
| *Of which due to:-* | | | | | |
| Market price support | 16712 | 17272 | 19041 | 20514 | 20529 |
| Direct support payments | 20627 | 20226 | 22154 | 24579 | 29357 |
| Other grants and subsidies | 4636 | 5133 | 5575 | 4618 | 7121 |
| Transfers to farmers (£) | 28337 | 28112 | 30260 | 31909 | 37878 |
| *Of which due to:-* | | | | | |
| Market price support | 9497 | 9710 | 10589 | 11686 | 11629 |
| Direct support payments | 16254 | 15522 | 16766 | 17879 | 22811 |
| Other grants and subsidies | 2586 | 2880 | 2905 | 2344 | 3437 |
| *As % of post-transfer income* | 99% | 95% | 110% | 87% | 104% |
| Pre-transfer income (£) | 304 | 1411 | -2650 | 4661 | -1551 |
| *Proportion of farms <0* | 57.6% | 56.9% | 58.2% | 52.4% | 56.7% |

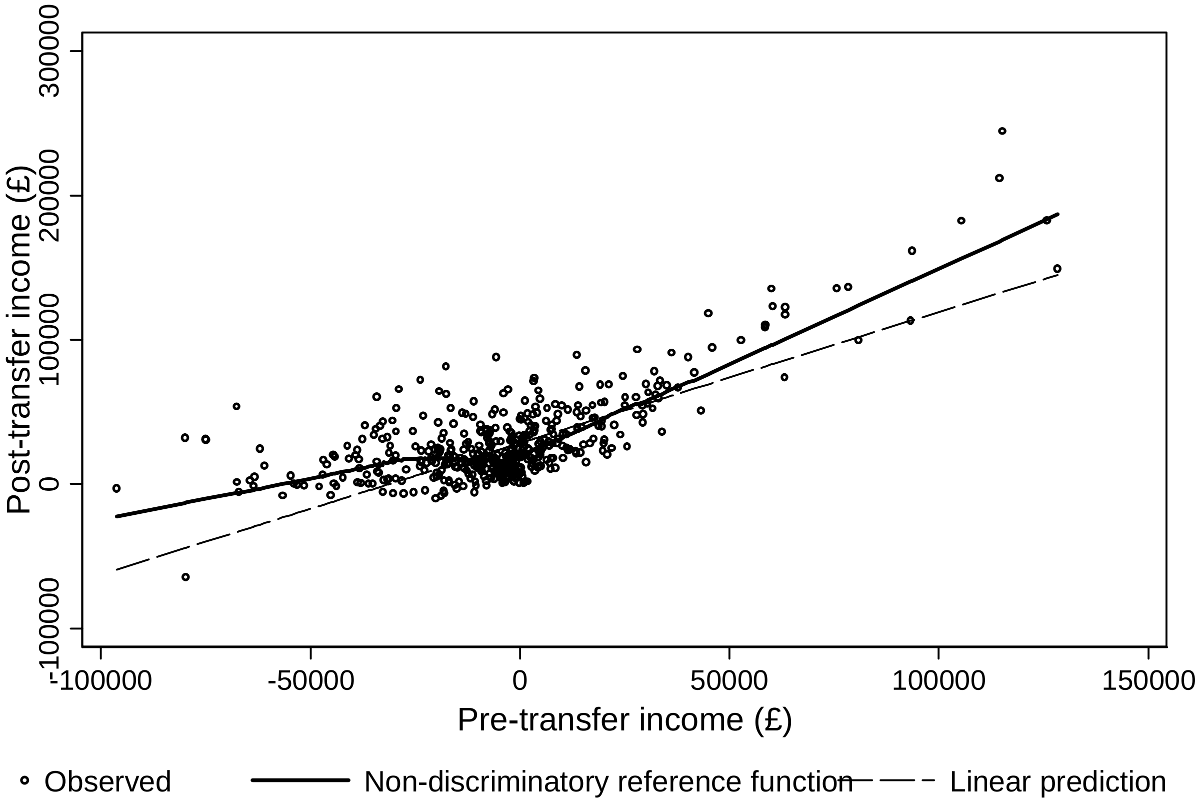
| *By farm type for all years* | All | Cereals | General Cropping | Dairy | Specialist Sheep | Specialist Cattle | Mixed Cattle & Sheep | Mixed |
|---|---|---|---|---|---|---|---|---|
| | | | | *Annual average per farm* | | | | |
| Number of observations | 423 | 32 | 47 | 58 | 50 | 100 | 80 | 32 |
| *% of raised sample* | | 15.8% | 12.8% | 10.3% | 10.0% | 22.8% | 16.7% | 15.8% |
| Farm business size (ESU) | 59 | 60 | 107 | 96 | 25 | 40 | 44 | 59 |
| Post-transfer income (£) | 31734 | 29065 | 43338 | 53748 | 16325 | 26116 | 28424 | 31853 |
| *Proportion of farms <0* | 6.9% | 16.8% | 4.6% | 0.7% | 4.1% | 5.8% | 5.8% | 5.9% |
| Gross support (£) | 47619 | 30671 | 38723 | 69859 | 28545 | 52084 | 54360 | 58000 |
| *Of which due to:-* | | | | | | | | |
| Market price support | 18814 | 4920 | 11124 | 58045 | 6017 | 20350 | 18028 | 20611 |
| Direct support payments | 23389 | 25066 | 26391 | 10285 | 13106 | 24514 | 25391 | 32621 |
| Other grants and subsidies | 5417 | 685 | 1207 | 1530 | 9423 | 7220 | 10941 | 4769 |
| Transfers to farmers (£) | 31299 | 19369 | 23530 | 40750 | 21569 | 36432 | 37217 | 36858 |
| *Of which due to:-* | | | | | | | | |
| Market price support | 10622 | 2745 | 6037 | 33059 | 3462 | 11633 | 10155 | 11393 |
| Direct support payments | 17847 | 16227 | 16781 | 6562 | 12778 | 20890 | 22338 | 22548 |
| Other grants and subsidies | 2830 | 397 | 712 | 1129 | 5329 | 3909 | 4724 | 2917 |
| *As % of post-transfer income* | 98.6% | 66.6% | 54.3% | 75.8% | 132.1 | 139.5 | 130.9 | 115.7 |
| Pre-transfer income (£) | 435 | 9696 | 19808 | 12998 | -5244 | -10316 | -8793 | -5005 |
| *Proportion of farms <0* | 56.4% | 39.6% | 24.2% | 31.8% | 67.8% | 78.5% | 73.6% | 56.2% |

Source: Own calculations using FAS data.

The lower panel of Table 2 presents comparable summary information for the seven distinct farm types identified in the analysis.[14] Post-transfer income levels were highest on dairy farms, and lowest on specialist grazing livestock farms which are typically smaller businesses on poor quality land. Direct payments provided the main source of both support and transfers for all farm types other than dairy, with payments based on areas planted accounting for the bulk of support on arable farms and payments based on livestock numbers doing likewise on sheep and cattle farms. Gross support varied across types, with dairy farms receiving the highest and specialist sheep farms the lowest levels of support on average. Average transfers to farmers follow a broadly similar pattern but differences in average transfer efficiency rates lead to a lower degree of variation across farm types. Overall, the dispersion of average incomes by farm type was lower for post-transfer incomes than for pre-transfer incomes, implying that the provision of support generally served to reduce rather than exacerbate income disparities between farm types in Scotland. OECD (2003, Part I) reports that the provision of support typically increases average income disparities between farm types, but that this is not the case in all countries.

Figure 1 illustrates the nature of the reference functions using the non-parametric estimation results for 2000/01. The top panel provides a scatterplot of the data on pre-transfer and post-transfer incomes, overlaid by the non-discriminatory reference function $h_B(\boldsymbol{x})$ and the linear regression of post-transfer on pre-transfer incomes. The plot shows that higher post-transfer incomes are generally associated with higher pre-transfer incomes and that the non-parametric regression model fits the data better than the linear model. The latter point is reinforced by the regression summary statistics reported in Table 3, which show that the predictive power of the non-parametric model, defined as the square of the correlation coefficient between the fitted and observed values (see Zheng and Agresti, 2000), is superior to that of the linear model in all years. Pre-transfer income is highly significant in the linear

Figure 1. Non-parametric reference functions



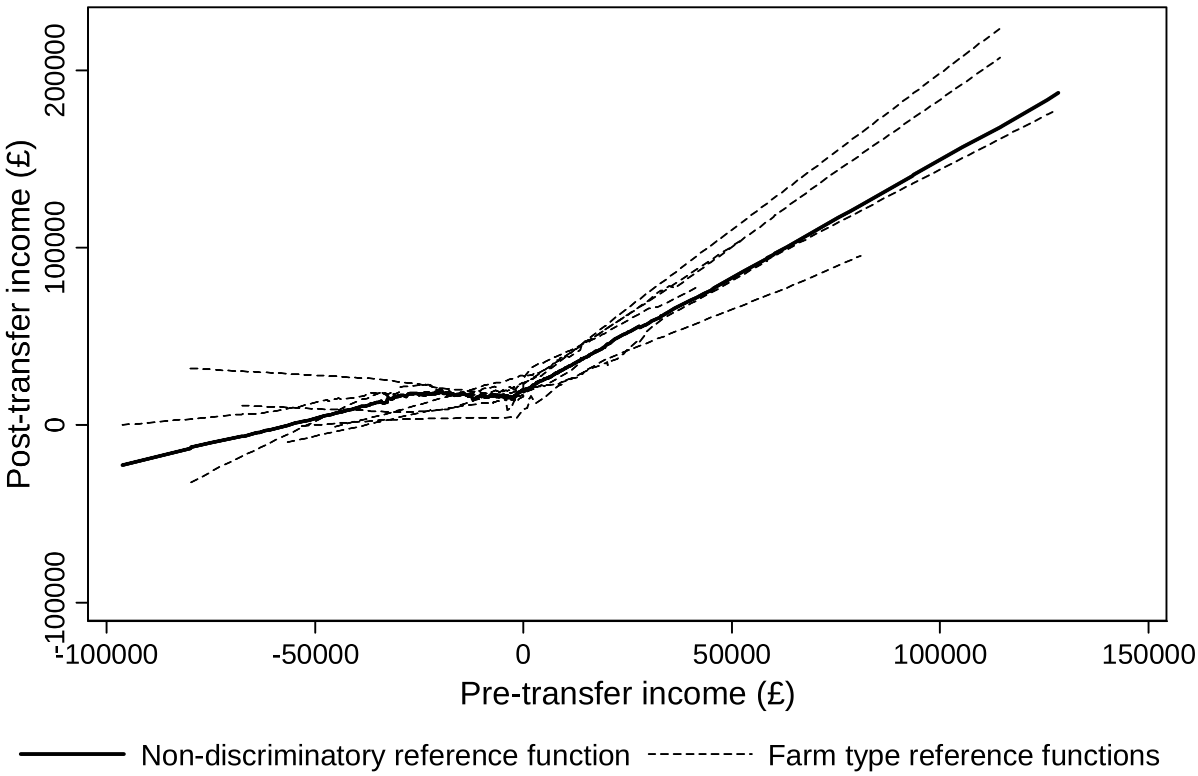



Table 3. Summary statistics from reference function regressions

| | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 |
|---|---|---|---|---|---|
| *Predictive power of:* | | | | | |
| Linear regression model | 0.626 | 0.540 | 0.297 | 0.612 | 0.340 |
| Non-discriminatory reference function $h_B(\boldsymbol{x})$ | 0.738 | 0.654 | 0.465 | 0.680 | 0.510 |
| Farm type specific reference function $h_W(\boldsymbol{x})$ | 0.805 | 0.749 | 0.625 | 0.761 | 0.627 |
| | | | | | |
| *F test of:* | | | | | |
| Pre-transfer income effect in the linear model | 751.3 | 452.1 | 158.3 | 699.6 | 236.2 |
| | (6.7) | (6.7) | (6.7) | (6.7) | (6.7) |
| Linearity in the non-discriminatory function $h_B(\boldsymbol{x})$ | 77.2 | 71.8 | 68.5 | 47.8 | 48.5 |
| | (7.0) | (8.2) | (8.4) | (8.4) | (4.8) |
| Farm type effects in the farm type function $h_W(\boldsymbol{x})$ | 6.4 | 4.9 | 6.8 | 13.9 | 5.7 |
| | (2.1) | (2.0) | (2.1) | (5.2) | (2.1) |

Critical values for 1% significance of the F statistics are reported in parentheses.

model, but the assumption of linearity is consistently rejected in favour of the non-discriminatory function using an F test procedure (Cleveland and Devlin, 1988, p.599).

The bottom panel of Figure 1 displays the non-discriminatory function $h_B(\boldsymbol{x})$ together with the set of farm type reference functions $g_k(\boldsymbol{x_k})$. The figure shows some divergence of the farm type functions about the non-discriminatory function, but the same positive association between post-transfer and pre-transfer incomes is generally apparent for each farm type over the observed range of pre-transfer incomes. From Table 3, the predictive power of the set of farm type functions is consistently superior to that of the non-discriminatory function. The F test procedure rejects the set of restrictions implicit in the pooled non-discriminatory function in all years, implying that farm type had a significant influence on the level of post-transfer income conditional on pre-transfer income.

Table 4 presents the main findings of the study. Absolute inequality in post-transfer farm incomes is shown to have been substantial with the average absolute income differential between farms comparable in size to average income levels throughout the period. In comparison, the distribution of pre-transfer income exhibited somewhat lower levels of absolute inequality. The provision of support thus increased absolute income differentials as indicated by the negative values of the index of net redistributive effect *R* which are all significantly different from zero at the 5% level or higher. Overall, agricultural policy increased average income disparities by between 10 and 30 per cent depending on the year.

Table 4. Redistributive effects of agricultural support policy, 1995/96-1999/00

| | | 2000/01 | 2001/02 | 2002/03 | 2003/04 | 2004/05 |
|---|---|---|---|---|---|---|
| Absolute Gini index of post-transfer income | $A_Y$ | 15754 | 16350 | 14299 | 16532 | 17788 |
| | | (1214) | (853) | (793) | (915) | (897) |
| Absolute Gini index of farm type specific reference income | $A_W$ | 12324 | 12788 | 10197 | 12868 | 12266 |
| | | (1341) | (981) | (973) | (1128) | (1038) |
| Absolute Gini index of non-discriminatory reference income | $A_B$ | 11596 | 11257 | 7701 | 12008 | 10550 |
| | | (1441) | (1095) | (1206) | (1282) | (1245) |
| Absolute concentration index of non-discriminatory reference income | $\bar{y}_B\, C_B$ | 11440 | 11240 | 7503 | 12005 | 10217 |
| | | (1500) | (1300) | (1449) | (1421) | (1505) |
| Absolute Gini index of pre-transfer income | $A_X$ | 14188 | 13212 | 10664 | 13730 | 13473 |
| | | (1030) | (818) | (649) | (759) | (796) |
| Index of redistributive effect | $R$ | -1566 | -3137 | -3635 | -2802 | -4315 |
| | | (659) | (703) | (795) | (578) | (857) |
| Index of vertical redistribution | $V$ | 2748 | 1972 | 3161 | 1725 | 3256 |
| | | (898) | (960) | (1511) | (1110) | (1366) |
| Disparity of net transfers | $D$ | 0.097 | 0.068 | 0.102 | 0.053 | 0.087 |
| | | (0.027) | (0.028) | (0.039) | (0.030) | (0.030) |
| Mean non-discriminatory transfers | $\bar{t}_B$ | 28325 | 28949 | 30987 | 32638 | 37557 |
| | | (2257) | (2380) | (2831) | (2748) | (3147) |
| Index of systematic reranking | $H_R$ | -156 | -17 | -198 | -3 | -334 |
| | | (281) | (538) | (574) | (322) | (659) |
| Total classical horizontal inequity | | -4159 | -5093 | -6598 | -4524 | -7238 |
| | | (600) | (744) | (1034) | (728) | (894) |
| *Of which:* Between farm type | $H_B$ | -728 | -1531 | -2496 | -860 | -1716 |
| | | (409) | (487) | (664) | (454) | (646) |
| Within farm type | $H_W$ | -3431 | -3561 | -4101 | -3664 | -5522 |
| | | (394) | (496) | (647) | (478) | (585) |

Notes: Own calculations using FAS data. All measures are calculated using the population-weighted data. Absolute Gini and concentration indices are estimated using the formulae in Lerman and Yitzhaki (1989) for weighted samples. Panel bootstrap standard errors, based on 1000 replications, are reported in parentheses and reflect not only the inherent sampling variability of the measures but also the need to estimate both factor cost shares and the set of reference functions in order to calculate them.

The decomposition of $R$ reveals four main points of interest. First, the distribution of non-discriminatory support was progressive in absolute terms, as indicated by the positive values of the disparity index $D$. By implication, farmers with negative or low pre-transfer incomes received more than an equal share of non-discriminatory transfers. This finding may appear surprising in the light of the commonplace observation that support is largely proportionate to the volume of production (see, for example, EC, 1991). But, gross support, transfers and non-discriminatory transfers are negatively not positively correlated with pre-transfer incomes, given that many farmers have to engage in otherwise loss-making activities in order to benefit from support.

Second, agricultural policy would have reduced the degree of absolute inequality in the distribution of farm incomes had it not been for horizontal inequities in the provision of support. The progressive distribution of non-discriminatory transfers results in the positive index of vertical redistribution $V$. However this positive gross redistributive effect was more than offset by the combined effects of the various sources of horizontal inequity, as measured by the indices $H_R$, $H_B$ and $H_W$. Annual transfers could have been cut by between about £4000 and £8000 per farm with no effect on welfare if it had been possible to devise a horizontally equitable support regime. These findings point to the importance of taking horizontal inequities into account in any consideration of the redistributive performance of agricultural policy.

Third, the unequal treatment of pre-transfer income equals was the dominant source of horizontal inequities, with none of the estimates of the systematic reranking effect significantly different from zero at the 5% level. This is not to say that the unequal treatment of pre-transfer income equals did not result in substantial reranking of farms between the pre-transfer and post-transfer income distributions, for which Allanson (2005a, 2006) provide ample evidence. Rather, once account has been taken of classical horizontal inequities in the provision of support, the results provide no evidence of systematic reranking due to the existence of income traps in the non-discriminatory function $h_B(\boldsymbol{x})$, whereby an increase in pre-transfer income over some range is associated with a decrease in expected post-transfer income. Moreover, there is little evidence of such traps in the farm type functions either, with systematic reranking accounting for no more than one third of total horizontal inequities within any one farm type in any year, and only 6.6% on average over all types and years.

Finally, the redistributive effect of within farm type HI consistently exceeds that of between farm type HI, though the estimates of the latter are significantly different from zero at the 10% level or higher in all years. The former arises from the dispersion of post-transfer incomes about farm type reference incomes $h_W(\boldsymbol{x})$, whereas the latter stems from systematic divergences between farm type and non-discriminatory reference incomes, $h_W(\boldsymbol{x})$ and $h_B(\boldsymbol{x})$ respectively. The results therefore imply that factors other than farm type were dominant in determining differences in the value of transfers received by individual farms with a particular level of pre-transfer income. Nevertheless there is evidence of systematic discrimination between farm types in the provision of support, which operated to the particular advantage of dairy and cattle farms and to the detriment of arable and sheep farms.[15] By implication, the disparities in average transfers reported in Table 3 are not solely due to differences in the distribution of pre-transfer incomes across farm types.

## 4. Conclusions

The principal focus of the paper is the characterisation and measurement of the redistributive effects of agricultural policy. One possible criticism of such an exercise is that the distribution of agricultural policy transfers reflects goals other than farm income support, such as those to do with the environment, sustainability and rural development. However measures specifically targeted to these other objectives still only account for a relatively small share of the gross value of support for Scottish agriculture, whereas the direct support payments that were introduced by the 1992 reform of the CAP and now account for the bulk of transfers, had the stated objective of compensating farmers for the adverse income effects of cuts in support prices. The European Commission has for many years expressed concerns about the inequitable distribution of income support (EC, 1991, 1997, 2002) and in the recent Mid Term Review of Agenda 2000 made various proposals to improve the targeting of direct support payments (EC, 2002, 2003). More generally, the measurement of redistributive effects may usefully inform the design of agricultural support policy by suggesting ways in which it might be made more effective as a redistributive tool, even though this is only one of several criteria by which to evaluate policy performance.

The redistributive effect of agricultural policy is measured as the difference between the absolute Gini indices of pre-transfer and post-transfer incomes. This is a measure of the change in absolute inequality, which provides a benchmark of distributional neutrality more in accord with both public and official perceptions of fairness in the distribution of agricultural support than one based on the concept of relative inequality. The measure may be interpreted as the monetary value per farm of the change in inequality due to the provision of support. Moreover it is shown that it may be decomposed into a vertical redistribution effect and various HI components, and thus serves not only to quantify but also to characterise the redistributive effect of agricultural policy.

The measure is used to explore the effects of agricultural policy on the distribution of Scottish farm incomes over the period 2000/01 to 2004/05. The empirical results show that the provision of support increased the average size of farm income differentials throughout the period. Nevertheless, the vertical stance of agricultural policy was consistently progressive in absolute terms, with non-discriminatory transfers decreasing in pre-transfer incomes. And it is only because of the adverse distributional effects of horizontal inequities that the provision of farm income support did not in fact reduce absolute inequality. The results further demonstrate that the main source of these inequities was the unequal treatment of pre-transfer income equals rather than the systematic reranking of farms between the pre-transfer and expected post-transfer income distributions. Moreover, the main factor underlying such classical horizontal inequities was the weakness of the relationships between transfers and pre-transfer incomes within each farm type, rather than systematic discrimination between types due to the commodity organisation of agricultural policy.

The imperfect targeting of support revealed by the empirical findings has implications for the design of agricultural policy. Historically, the wide variation in transfer levels between farms with similar pre-transfer incomes suggests that policies designed to limit the size of production-related payments to larger farms would have been largely ineffective as a means to concentrate support on those farms capable of generating only low levels of farm income. Moreover, there seems to have been only limited scope to improve targeting through either the elimination of income traps in transfer schedules or the rebalancing of support across commodity regimes, given that neither systematic reranking nor systematic discrimination between farm types appears to be the main source of horizontal inequities. Looking to the future, the decoupling of direct support payments will break the link between current production choices and the receipt of subsidies, with farmers merely required to keep their land in good agricultural and environmental condition. In the case of Scotland, this is likely to further weaken the relationship between support and pre-transfer incomes because entitlements to the new decoupled payment will be "grandfathered" on the basis of historical payment receipts. More generally, the impact of decoupling on the potential for targeting support in an efficient and effective manner will depend on the strength of the correlation between the indicator employed to determine payment entitlements and (post-decoupling) pre-transfer income.

**Acknowledgements**

The author would like to thank the Scottish Executive Environment and Rural Affairs Department for making available the data employed in the study. All opinions expressed in this paper are solely the responsibility of the author.

**Footnotes**

1 Losses have often been treated as nuisance items in agricultural income distribution studies with one common practice being to set all negative incomes to zero (see, for example, Ahearn et al. 1985) even though this will obviously bias resultant measures of inequality (Schutz 1951).

2 $A = \left\{ \frac{1}{2n(n-1)} \sum_{i=1}^{N} \sum_{j=1}^{N} | y_i - y_j | \right\}$ where $y_i$ is the income of observation $i$ ($i$=1,..$N$).

3 The Lorenz curve of $h_W(\boldsymbol{x})$ will lie everywhere on or above that of $\boldsymbol{y}$ since $h_W(\boldsymbol{x})$ may be obtained from $\boldsymbol{y}$ through a series of progressive mean-preserving transfers (Dasgupta *et al.*, 1973). Hence the inequality of $h_W(\boldsymbol{x})$ will be equal to or lower than that of $\boldsymbol{y}$, since the absolute Gini coefficient satisfies the weak principle of transfers and $H_W$ will be non-positive. However, this condition may not necessarily hold exactly in any finite sample of farms drawn from the population.

4 This follows because the Lorenz curve of $h_B(\boldsymbol{x})$ will lie everywhere on or above that of $h_W(\boldsymbol{x})$ as $h_B(\boldsymbol{x})$ is a weighted average of the $g_k(\boldsymbol{x})$ functions (Kakwani and Lambert, 1999).

5 $C_B$ is defined in relation to the concentration curve obtained by plotting the cumulative proportion of non-discriminatory post-transfer income against the cumulative proportion of the population ranked by without-support income in the same way that $G$ is defined in relation to the ordinary Lorenz curve. Note that $C_B = G_B$ if the ranking of farms by pre-transfer and non-discriminatory post-transfer incomes is identical.

6 One can also measure the extent of systematic reranking induced within each farm type by the individual farm type reference functions in (1). However aggregation of these measures across types to yield an overall reranking index is problematic. Between type classical HI is therefore identified prior to the reranking effect, rather than vice versa.

7 $C_{T_B}$ is defined analogously to $C_B$. Note that $C_{T_B}$ will be negative (positive) if farmers with low pre-transfer incomes receive a larger (smaller) share of support than those with high ones, and will equal zero for a universal flat-rate benefit.

8 To check the sensitivity of the empirical findings to the choice of variable span, results were also derived using spans 50% smaller and 50% larger than that chosen by the smoother. The resultant redistributive effect estimates were very similar to those reported in the paper, confirming the conclusions about the nature and significance of horizontal inequities in the provision of support.

9 Farms that were directly affected by foot and mouth disease (FMD) culls and compensation are excluded from the analysis, but the resultant sub-samples for 2001/02 and 2002/03 are nevertheless sufficient "to give a representative picture of full-time Scottish farm businesses" in these years (SEERAD, 2003, 2004).

10 The sampling frame excludes small farms less than 8 Economic Size Units (ESUs) prior to 2003/04 and 0.5 Standard Labour Requirements (SLRs) thereafter; specialist livestock units larger than 200 ESU prior to 2003/04; and certain minor farm types (most notably horticulture and specialist pigs and poultry farms).

11 This group may include not only the farmer and spouse but also non-principal partners and directors and their spouses and family workers.

12 These schemes are listed in the Annex to Council Regulation (EC) No. 1257/1999 and include the Arable Area Payment, Sheep Annual Premium, Suckler Cow Premium, Beef Special Premium and Extensification Payment schemes.

13 Ideally, it would have been possible to specify a common technology for each farm type but reliable estimates of the output elasticities could not be obtained on this basis due to the limited number of observations on some farm types.

14 The farm type classification in all years is based on '1988' standard gross margins to ensure comparability over time. Cereals, general cropping, dairy and mixed farm types are identical to the eponymous UK robust types. The specialist sheep farm type corresponds to EC type 441, specialist cattle to EC types 421 and 422 combined, and cattle & sheep to EC types 431, 432, 442 and 444 (as implemented in the UK) combined. See DEFRA (2002, Appendix 2) for further description of the classification scheme.

15 Discrimination is taken to be to the advantage (detriment) of a particular farm type if the weighted average value of $h_W(\boldsymbol{x})$ for that farm type is greater (less) than that of $h_B(\boldsymbol{x})$.

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